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News Briefs

General Developments

Inquiries about News Briefs, where no contact person is identified, should be referred to the Managing Editor, Journal of Research, National Institute of Standards, and Technology, Building 101, Room E215, Gaithersburg, MD 20899-2500; telephone: (301) 975-3577.

NIST ESTABLISHES REFERENCE FOR MEASURING FREQUENCY DEPENDENCE OF CAPACITORS

Recent work at NIST could lead to improvements in the capacitance calibration services at NIST by a factor of three or four. The primary maintenance standard for NIST capacitance calibrations consists of a bank of four 10 pF fused-silica standards (referred to as the Farad Bank) which are maintained in an oil bath at 25 °C. The Farad Bank is calibrated twice a year against the calculable capacitor at a frequency of 1592 Hz. The calculable capacitor provides an absolute determination of capacitance in terms of length only and is the ultimate reference for all impedance measurements in the United States. Until recently, there was a lack of a well-characterized reference capacitor over the audio frequency range, resulting in large assigned uncertainties for capacitance calibrations to account for the uncharacterized frequency dependence of the Farad Bank.

The value of a standard capacitor may vary slightly with frequency because the imperfect medium between its electrodes has varying degrees of dielectric relaxation over the frequency range and the leads and electrodes of the capacitor have residual inductance. Using a combination of a 1 pF cross capacitor that has negligible frequency dependence due to electrode surface films and a 10 pF nitrogen dielectric capacitor with a very small residual inductance as references, NIST staff have measured the frequency dependence of two 10 pF transportable fused-silica capacitors from 50 Hz to 20 kHz. The relative standard uncertainties determined at 400 Hz and 100 Hz (0.15×10^{-6} and 0.32×10^{-6}, respectively) are smaller than the uncertainties previously assigned to frequency dependence at these frequencies by a factor of five. This will lead to improvements in the capacitance calibration services at NIST by a factor of three or four.

The results were presented in an invited talk in August at the 2003 National Conference of Standards Laboratories; an archival paper describing the work has been published in the September issue of *Review of Scientific Instruments*. NIST plans to transfer the frequency dependence data to the Farad Bank and other reference capacitance standards, so that in the near future, improved capacitance calibrations will be available from NIST for the entire audio frequency range.

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MEASUREMENT/CALIBRATION TECHNIQUE FOR NANOMETER SCALE AVERAGE FILM THICKNESS ON ATOMICALLY ROUGH SURFACES DEVELOPED

Current magnetic hard disks are protected by a nanometer-thick layer of alcohol functionalized perfluoroakylether and carbon overcoat. Achievement of higher areal density requires further reduction in the space between the head and the magnetic layer at higher speed. The possibility of occasional impacts from head disk collisions requires that the adhesive strength of the organic molecules be increased while retaining the mobility of some of the molecules. One possible solution is to use a mixed molecular assembly in which two separate species are assembled together to impart both adhesive strength and mobility. Because of the poor solubility characteristics of perfluoroakylethers, such mixed films are very difficult to achieve. Hydrocarbon molecules can be used for this purpose. One technical barrier is the measurement of average film thickness at 10 Å ± 1 Å on a surface with 15 Å to 25 Å peak-to-valley distance. There is no widely accepted analytical technique for measuring this thickness accurately and consistently.

To address this issue, a master calibration sample was created by depositing a known mass of hydrocarbon molecules in a dilute solution on magnetic hard disk surfaces and allowing the solvent to evaporate slowly. Knowing the mass of the film and the bulk density of the material, the thickness of the film can be calculated. To achieve uniformity of deposition and evaporation, it was necessary to confine the solution to a known area and to overcome the wetting and meniscus forces during the deposition and evaporation processes. A barrier film was used to define the area. Then, the solution was frozen and the solvent was allowed to evaporate slowly under a controlled atmosphere. The procedure was carried out in a clean room to minimize potential contaminants.

This technique has been used successfully to deposit films with a range of hydrocarbon thickness from 3 Å to 25 Å, using disks of different roughness (isotropic and anisotropic), different carbon overcoat thickness, and different carbon overcoat chemistry (hydrogenated carbon, nitrogenated carbon, and a mixed hydrogenate/nitrogenated carbon). Consequently, this method can be applied to a variety of engineering surfaces for film thickness measurement, and it can be used to calibrate different analytical techniques used for such measurements.

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NIST RESEARCHERS QUANTIFY CELLULAR VIABILITY AND INFLAMMATORY RESPONSE TO DENTAL BONDING RESINS

Implanted biomaterials frequently evoke inflammatory responses, which are subsequently responsible for biomedical implant failures. NIST researchers have developed a metrology for the analysis and quantitation of cellular inflammatory responses in vitro. The technique will accelerate biomedical device development by minimizing or eliminating the need for expensive in vivo animal testing.

Real-time polymerase chain reaction (RT-PCR) and flow cytometry were used to quantify elevated cytokine production as an indicator of inflammatory responses to four commercial dental resins. (Cytokines are proteins that are responsible for regulating both the duration and intensity of immune responses and for mediating intercellular communication.) Murine macrophages cells exposed to resins containing Bis-GMA (2,2-bis[*p*-(2'-hydroxy-3'-methacryloxypro-poxy) phenyl]propane) and HEMA (2-hydroxyethyl methacrylate) had the most adverse responses, as indicated by the relative proportion of live cells to dead cells. Moreover, the other resin systems displayed intermediate levels of viability when compared with the untreated control. The results demonstrate that cellular response to toxic leachables follows a distinct pathway, starting with up-regulation (elevated production) of proinflammatory cytokines and, depending on the strength of the response, terminating in extensive necrosis (localized death of living cells).

For additional information, visit the Polymers Division Web site at www.nist.gov/polymers.

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NIST RESEARCHER DEVELOPS PROTOTYPE AUTOMATED COMMISSIONING TOOL WITH FRENCH SCIENTIFIC AND TECHNICAL BUILDING CENTER (CSTB)

A NIST researcher participated in a 3 month collaboration with CSTB in Paris, France, to develop an automated commissioning tool for building air handling units. After developing the concept for an automated commissioning tool, NIST partnered with CSTB to code the fault detection algorithm, develop the graphical user interface, and test the prototype tool on a real system. The retro-commissioning project took place in the ARIA Building at CSTB where none of the three constant air volume air-handling units had been previously commissioned. By interfacing the automated commissioning tool to the building energy management system, test scripts can automatically command changes to system setpoints to achieve various operating states and document system responses. In preliminary results, several faults having significant impacts on energy consumption and occupant comfort were identified, including sensor errors and improper setpoints.

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NIST PARTICIPATES IN DEMONSTRATION OF FIRST RESPONDER TECHNOLOGIES TO FIREFIGHTERS

On July 16, 2003, NIST hosted a meeting of firefighters and rescue personnel to demonstrate technologies under evaluation by the NIST Distributed Testbed for First Responders. In attendance were fire chiefs/commissioners and their associates from communities in Phoenix, Ariz.; New York City; Wilson, N.C.; King of Prussia, Pa.; Arlington, Charlottesville,

Fairfax, and Prince William, Va.; and Fort Meade and Montgomery County in Maryland. A discussion on the needs and priorities of first responders followed the demonstration.

The technologies demonstrated included access to building information database and dynamic building status from sensors, sensor-driven fire model using the NIST Virtual Cybernetic Building Testbed simulator, standardization of communications interface for sensors, biometrics for identification and authentication, dynamic self-organizing wireless networks for voice and data, voice over Internet, and emergency personnel localization and tracking.

NIST established the Distributed Testbed for First Responders to evaluate different technical approaches and to carry out the NIST mission of assisting industry in the development of standards for interoperability and open systems. The testbed, which builds on work already under way at NIST, will enable collaborative research at NIST on issues relating to improving the safety and effectiveness of first responders. Research will be conducted on a variety of topics, including developing and demonstrating highly capable communication and localization systems, increasing the quality and quantity of information available to first responders, improving information display and decision support systems, and the seamless integration and interoperability of smart wireless sensor networks in buildings.

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NIST UPDATES HEALTH CARE COMMUNITY ON IT SECURITY WORK

On July 29, 2003, the Security Health Care Certification and Accreditation Work Group met at NIST to review the latest work at NIST regarding IT security standards and guidelines. Approximately 60 people participated in the meeting, of which about 90 % were private-sector health care service/support providers. The participants were interested in learning and assessing relevant NIST IT security standards and guidelines they could draw upon to aid the community in complying with requirements of the Health Insurance Portability and Accountability Act (HIPAA) Final Security Rule that was issued by the U.S. Department of Health and Human Services (HHS) in February 2003. The HIPAA Final Security Rule identifies NIST and several IT security documents as sources of information.

NIST provided presentations on draft NIST Special Publication (SP) 800-37, *Guidelines for the Security Certification and Accreditation of Federal Information Technology Systems*; draft Federal Information Processing Standard 199, Standards for Categorization of Federal Information and Information Systems; the status and overview of forthcoming draft NIST SP 800-53, *Guidelines for Selection and Specification of Security Controls for Information Systems; and draft SP 800-50, Building an Information Technology Security Awareness and Training Program.* (For copies of the draft documents, see http://csrc.nist.gov/publications/drafts.html.) NIST personnel also briefed the group on a joint NIST and Center for Medicare and Medicaid Services/HHS project to produce a resource guide of NIST information for supporting implementation of the HIPAA Security Rule.

URAC (also known as the American Accreditation HealthCare Commission), a 501(c)(3) non-profit charitable organization founded in 1990 to establish standards for the health care industry, is helping to coordinate the health care community in assessing security standards and best practices for health care information systems through the Security Health Care Certification and Accreditation Work Group. Ultimately, the workgroup hopes to develop a common set of health care security standards that will cover security policies, procedures, controls, and auditing practices for IT security in health care information technology systems.

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NIST ISSUES REFERENCE MATERIAL 8457 TO AID ORTHOPEDIC IMPLANT MANUFACTURERS AND RESEARCHERS

Reference material (RM) 8457, which consists of 0.5 cm cubes of orthopedic-grade ultra-high molecular weight polyethylene that are well suited for measurements of cross-link density by a new ASTM International swell-test method, has been issued. Scientists at NIST produced the RM in response to recent interest among manufacturers and researchers of orthopedic implants to improve wear performance by ionizing radiation treatments. These treatments are known to produce new chemical bonds (cross-linking) between the polymer molecules. The extent to which cross-linking occurs during the radiation treatment is an important design variable. In recognition of its importance, ASTM International issued a new standard test method for cross-linking, F2214-02: Standard Test Method for

In Situ Determination of Network Parameters of Crosslinked Ultra-High Molecular-Weight Polyethylene. The standard test method references RM 8457, along with results of a round-robin analysis of the method. NIST supplied specimens for the round-robin testing that were manufactured from the same material—RM 8456—as RM 8457.

The RM can be purchased at the Standard Reference Material/RM Web site: www.nist.gov/srm.

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NIST HELPS DEVELOP NEW METHOD TO ATTACH LONG-CHAIN ALIPHATIC MOLECULES TO SILICON

NIST scientists have developed an improved solution-based method for the direct attachment of long-chain aliphatic molecules to Si. In this method, ultraviolet radiation is used to assist the attachment of alcohols to the hydrogen-terminated Si(111) surface to successfully form molecular monolayers. To investigate the quality of these organic monolayers, they were physically and chemically characterized with infrared spectroscopy, spectroscopic ellipsometry, and contact angle measurements. The electrical properties of these organic films were probed by using current-voltage and capacitance-voltage (CV) measurements obtained from a metal-organic-silicon test structure fabricated by post-monolayer metal deposition. The effect of differing alkane chain length on the electrical properties was investigated, and the CVs are in agreement with traditional theory for a metal-insulator-semiconductor. Initial results of this research were presented at the 2003 meeting of the American Chemical Society.

Direct attachment of organic molecules to the silicon surface is of increasing importance for emerging molecular electronics applications as devices incorporating molecules chemically bonded to silicon are amenable to integration with existing Si processing techniques. In addition, the chemical bond between Si and organic molecules is stronger and, therefore, expected to be more stable than the metal-molecule bond typically used in the assembly of molecular electronic devices. However, forming this Si-molecule bond to create self-assembled monolayers can be difficult. Costly and time consuming ultra-high vacuum techniques are often used to attach molecules to Si.

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NIST MEASURES DIPOLE MOMENT OF SEMICONDUCTOR QUANTUM DOTS

NIST researchers have developed a new measurement technique for the characterization of semiconductor quantum dots (QDs), which are used in quantum computing, optical communication, and quantum cryptography applications. Little detailed knowledge of the transition dipole moment of QDs previously had been available, although it is critical in determining gain for QD laser design and in implementing the coherent manipulation of the QD state in quantum logic gates that may be part of future-generation optical computers.

A NIST researcher developed a new technique to directly measure the dipole moment of QDs and has applied it to self-assembled InGaAs/GaAs dots. It relies on the measurement of pulses of light that exit an optical waveguide containing the QDs as the light reflects multiple times from the waveguide facets. Light that is coupled out of the waveguide is mixed with a variably delayed gating pulse in a non-linear crystal to time resolve the output. The absorption co-efficient is determined by comparing the energy of successive pulses and taking into account the measured waveguide facet reflectivity and background absorption, as determined from measurements of a waveguide that does not contain QDs. The dipole moment is derived from the ground state absorption and the QD areal density, which was determined from transmission electron micrographs generated by collaborators at the National Renewable Energy Laboratory. Quantum dot density variation in the samples proved to be the largest source of uncertainty in the measurement.

The NIST dipole moment measurement technique overcomes the large uncertainties of other measurement techniques which were based on threshold currents of laser diodes, had large background material absorption, or had difficulty estimating coupling efficiency into and out of the QD region. Techniques are now being developed to directly measure the absorption of a single, isolated quantum dot.

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NIST DELIVERS HIGH ACCURACY CALIBRATION INSTRUMENT FOR NAVY OPTICAL FIBER SENSORS

A NIST scientist designed, characterized, and recently delivered a calibration instrument for optical fiber Bragg grating (FBG) strain and temperature sensors to the Naval Research Laboratory (NRL). This instrument will be used to calibrate the Navy's strain sensor read-

out units that will be deployed throughout the Navy fleet. The project was funded by the Navy's Coordination and Calibration Group.

FBGs are a periodic modulation of refractive index written directly into the core of optical fiber. This periodicity causes a narrow spectral bandwidth of the light traveling in the fiber to be selectively reflected from the FBG. The center wavelength of the reflected light changes as the FBG is subjected to strain and temperature changes, making FBGs attractive as small, lightweight, networkable sensors.

The calibration instrument delivered to the NRL contains four stabilized FBGs whose center wavelengths were accurately measured using both a tunable laser measurement system and low-coherence interferometry. Careful uncertainty analysis on both techniques yielded a 2 pm expanded uncertainty on the calibration instrument. It was found that the "stabilized" FBGs actually drift slightly with time (a few picometers per year). This instability illustrates the need for accurate metrology related to FBG characteristics. FBG sensors have potential uses in medical applications and as strain sensors to measure the structural integrity of buildings, bridges, and aircraft. NIST researchers are investigating FBG metrology needs for these applications.

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ULTRA-SMALL-ANGLE X-RAY SCATTERING (USAXS) IMAGING OF HUMAN AND ARTIFICIAL TISSUES

USAXS imaging is a high-contrast imaging technique being developed by NIST researchers. It provides direct images of the shapes and three-dimensional arrangement of the scattering objects within a sample that is unobtainable using conventional x-ray imaging methods. USAXS imaging, combined with USAXS analysis, provides information on the size distributions, shapes, and three-dimensional arrangements of scattering objects. When applied to human and artificial tissues, these techniques improve the understanding of these materials and assist in the development of new man-made biomaterials. The goal of this research is nondestructive observation of the critical structures responsible for the properties of natural and man-made tissues.

The following paragraphs describe our most recent results from USAXS imaging and USAXS analysis on human ankle cartilage and man-made tissue scaffolds.

USAXS images and USAXS scans were made of human ankle cartilage mounted in a wet cell to forestall dehydration. Images were recorded at locations near the bone/cartilage interface, in the center, and near the cartilage surface. Images taken with the scattering vector parallel to the cartilage surface showed few structures. Images taken with the scattering vector perpendicular to the surface showed copious structures both near the surface, where the collagen fibers are parallel to the surface, and on the opposite side near the bone where the collagen fibers are perpendicular to the bone. The middle of the sample showed few distinct structures supporting the model of "disorder" in this region.

Polymer-based tissue scaffolds for growing tissues are under development, but the degree of crystallinity on the pore surfaces can strongly affect cell growth. To explore this effect, a polymer scaffold (porous Poly-Capraloactone, PCL) was produced with an additional annealing/cooling step to alter the degree of crystallinity. USAXS scans from the tissue scaffolds contained a pronounced peak produced by the lamellar structure of the polymer. The density difference between the amorphous and crystalline phases of the scaffold leads to enhanced scattering at the boundaries. Comparison and superposition of the images made in radiographic mode and USAXS imaging mode allowed researchers to determine the locations of the crystallites relative to the pore surfaces, and an analysis of the scattering curve enabled them to extract the crystallite size distribution.

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SUBSCRIPTIONS TO ONLINE *JOURNAL OF PHYSICAL AND CHEMICAL REFERENCE DATA* INCREASE GREATLY

In December 1999, NIST changed to a sole partnership with the American Institute of Physics (AIP) in publishing the *Journal of Physical and Chemical Reference Data* (JPCRD). Since that time, AIP has vigorously marketed the journal and the number of print subscribers has stabilized. More importantly, AIP has included the journal in package offerings to consortia of academic and non-profit organization institutions. In late September 2003, AIP announced that the number of online subscribers had risen from 470 to today's total of 1128 institutions. The great increase dramatically improves the availability of NIST standard reference data and once again demonstrates the revolutionary nature of online dissemination.

The *Journal of Physical and Chemical Reference Data* is an internationally renowned publication

featuring articles evaluating published scientific data. Subjects include thermodynamics, thermophysics, atomic and molecular spectra, electron, atomic and molecular collisions, surface science and solubilities of substances. Articles in the journal are not subject to page constraints and contain comprehensive tables of recommended data values as well as detailed explanations of evaluation criteria and reviews of data generation procedures. About 50 % of the journal articles are authored by NIST data experts and the remainder come from scientists throughout the world. Since its inception in 1972, the journal has published over 626 articles, nine monographs, and 12 supplements, making it one of the largest ongoing handbooks of evaluated chemical and physical data in the world.
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ABSOLUTE SURFACE COVERAGE MEASUREMENT DEMONSTRATED USING VIBRATIONAL OVERTONES

Using evanescent-wave cavity ring-down spectroscopy (EW-CRDS), a technique pioneered at NIST, measurement of absolute surface coverage with submonolayer sensitivity has been demonstrated. The first C-H stretching overtones of trichloroethylene (TCE), cis-dichloroethylene, and trans-dichloroethylene were probed for the gas- and adsorbed-phase species using a seeded optical parametric amplifier. Polarized absolute adsorbate spectra were obtained by EW-CRDS using a high-finesse fused-silica monolithic optical resonator, while absolute absorption cross sections for the gas-phase species were determined by conventional CRDS. A measure of the average transition moment orientation on the surface, which is required for monolayer coverage determination, was derived from the polarization anisotropy of the surface spectra. As the vector-character of absorption yields only an average tilt angle to characterize the orientation distribution, the method is accurate for highly oriented, unimodal surface distributions. For such well-ordered systems, coverage uncertainties of ±0.1 monolayer are possible. The EW-CRDS technique also was shown to provide a significant advance in sensitivity for chemical detection of TCE, which is a major environmental contaminant.

This work, performed collaboratively by NIST and the Eindhoven University of Technology in the Netherlands, has been supported by the Environmental Management Science Program of the Department of Energy.
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NEW CD-ROM RELEASED

NIST has just released a new CD-ROM, entitled NIST Special Publication 1001, *Basic Mass Metrology,* specifically aimed at training metrologists in concepts, procedures, and mathematics (including simple statistics) needed for basic mass metrology. Created by NIST staff and contractors, the CD-ROM represents the culmination of a 3 year effort to provide an interactive, multimedia supplement/reinforcement for a basic mass metrology seminar.

A paper describing NIST efforts to create an effective CD is also available. The paper is posted at www.nist.gov/labmetrology. The paper shared the Best Paper Award at the 2003 Measurement Science Conference and was discussed at the 2003 NCSLI Workshop and Symposium.

The *Basic Mass Metrology* CD-Rom will supplement the training that is offered to weights and measures officials and ensure that they have the same basic knowledge when attending the NIST training sessions.
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NIST PUBLISHES NEW INFORMATION SECURITY GUIDELINES

NIST recently released five new information security guidelines as NIST special publications (SPs):

- NIST SP 800-35: *Guide to Information Technology Security Services.* The guide provides assistance with the selection, implementation, and management of IT security services by guiding organizations through the various phases of the IT security services life cycle. The factors to be considered when selecting, implementing, and managing IT security services include the type of service arrangement; service provider qualifications, operational requirements and capabilities, experience, and viability; trustworthiness of service provider employees; and the service provider's capability to deliver adequate protection for the organization systems, applications, and information.
- NIST SP 800-36: *Guide to Selecting Information Security Products.* The selection of IT security products is an integral part of the design, development, and maintenance of an IT security infrastructure. The guide defines broad security product categories, specifies product types within those categories, and provides a list of general characteristics and questions an organization can ask when selecting a product.
- NIST SP 800-42: *Guideline on Network Security Testing.* The guide stresses the need for an effective

security testing program within federal agencies. It identifies network testing requirements, discusses how to prioritize testing activities with limited resources, and describes several network security testing techniques and tools. Also presented is a framework for incorporating security into the information system development life cycle (SDLC) process. The guide seeks to help organizations select and acquire cost-effective security controls by explaining how to include information system security requirements in the SDLC.

- NIST SP 800-50: *Building an Information Technology Security Awareness and Training Program.* The publication provides detailed guidance on designing, developing, implementing, and maintaining a comprehensive awareness and training program as part of an organization's IT security program. It provides guidelines that can help federal agencies meet their security training responsibilities as contained in the Federal Information Security Management Act and Office of Management and Budget guidelines.
- NIST SP 800-64: *Security Considerations in the Information System Development Life Cycle.* The guide presents a framework for incorporating security into the information system development life cycle (SDLC) process. It seeks to help organizations select and acquire cost-effective security controls by explaining how to include information system security requirements in the SDLC.

The five security guidelines are available for down-load at http://csrc.nist.gov/publications/nistpubs/index.html.

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NIST RESEARCHERS DEVELOP HIGH-TEMPERATURE SUPERCONDUCTING MICROWAVE POWER LIMITER

Superconducting electronics are being explored for many high-performance communications applications that require very low insertion loss, or unsurpassed sensitivity or dynamic range. However, such high-performance superconducting components are vulnerable to damage if exposed to high-power transient signals, such as lightening strikes or unintentional radar illumination and thus need to be protected by an input microwave power limiter. Conventional power limiters would increase the insertion loss or significantly reduce the dynamic range of the system, thereby compromising the advantages of using superconducting components.

In order to address these issues, researchers have designed, fabricated, and tested a microwave power limiter based on high-temperature superconductor thin-film technology. In order to be compatible with the highest performance superconducting digital circuits, researchers have designed a limiter for minimum insertion loss and maximum possible bandwidth. The power limiter takes the form of a 50 Ω coplanar waveguide (CPW) transmission line fabricated from a $YBa_2Cu_3O_{7-\delta}$ film grown on a sapphire substrate. The CPW transmission line is reversibly driven from the low-loss superconducting state to the high-loss normal state when the microwave currents within the device exceed a critical value. When operated at 70 K, the signal limiter displays very low insertion loss and extremely wide bandwidth in the nonlimiting state with constant impedance over the entire microwave range, making it essentially "transparent" to the system. When the input power exceeds the designed limit, the device switches into the normal state, effectively blocking the signal above the critical value. The device provides only the amount of attenuation that is needed and continues to pass a portion of the incident signal during the overpower event.

One of the key parameters of a microwave power limiter is its switching time. In order to protect sensitive components from high-power signals, the limiter must turn on in a sufficiently short period of time. The researchers have demonstrated that the superconducting limiter switches from the non-limiting to the limiting state in less than a nanosecond, with no detectable leakage through the device on this time scale. The superconducting limiter is now being evaluated for use in a variety of high performance communication systems.

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NIST RESEARCHERS MODEL ANTI-REFLECTION STRUCTURES FOR PHOTON NUMBER RESOLVING OPTICAL DETECTORS

NIST researchers have successfully modeled anti-reflection structures that could be used with tungsten superconducting transition-edge sensors (TES) to increase the quantum efficiency of detection of a 1.55 μm photon from 20 % to 98.5 %. By using a reflecting layer underneath the detector metal layer (tungsten) and a single layer anti-reflection coating above the tungsten, the quantum efficiency of a photon being absorbed in the tungsten can be significantly enhanced. After carefully measuring the optical properties of thin films of tungsten, silicon oxide, and silicon nitride fabricated in a NIST cleanroom, optical meas-

urements of anti-reflection structures agreed with numerical calculations for their performance. A structure with >98.5 % absorption of photons in a tungsten film was fabricated. In principle, >99 % absorption should be possible with better control of thicknesses of the various films.

Improvements in the quantum efficiency of detection for tungsten films fabricated into TES sensors will have a significant impact on several areas of research, including metrology for quantum key distribution systems, quantum optics, and linear optical quantum computing.

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NIST PHOTON NUMBER RESOLVING DETECTORS CONTRIBUTE TO QUANTUM KEY DISTRIBUTION

In collaboration with a team of researchers at Los Alamos National Labs (LANL), researchers at NIST have, for the first time, combined the fiber-based quantum key distribution system demonstrated by the LANL team with the photon number resolving detectors developed by NIST. The fiber-based system used light from a weak coherent laser pulse at 1310 nm to transmit key material and attenuators between the transmitter and receiver to simulate fiber losses over long distances.

As part of the Defense Advanced Research Projects Agency's Quantum Information Science and Technology program, NIST researchers have designed and built a prototype single photon detection system that has demonstrated the ability to count the number of photons in a short pulse of light with no dark counts. The detectors are superconducting transition-edge sensors (TES), optimized for the detection of optical and telecommunication wavelength photons. Each photon or group of photons absorbed by the TES devices produces a signal that is a short current pulse with a relatively fast rise time, <1 μs, and a decay time of 20 μs.

With conventional detectors, the dark count rate is responsible for an increased error rate and, consequently, a loss of security over long distances. Because of the extremely low dark count rate with a TES detector, it should be possible to securely transmit key material over longer distances (≈100 km).

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NIST SUCCESSFULLY MITIGATES NOISE IN SUPERCONDUCTING THIN-FILM SENSORS

NIST researchers are building large-format arrays of cryogenic sensors for materials analysis and astronomy. The performance of these sensors has been limited by excess noise sources not explained by existing theories. Researchers recently measured sensors with different geometric noise-mitigation features and identified designs in which the excess noise is heavily suppressed. The most interesting features implement normal-metal bars across the sensor in the direction perpendicular to the current flow. These results provide clearer understanding of noise sources in superconducting films. It is hoped that these designs will result in improved detector performance.

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FIBER LASER-BASED FREQUENCY COMB FOR FREQUENCY METROLOGY IN THE INFRARED DEVELOPED BY NIST

NIST staff recently developed a phase-locked "frequency comb" in the 1100 nm to 2200 nm wavelength region using fiber optic technology. This novel frequency comb should enable high-precision frequency metrology experiments in the near infrared and, in particular, across the telecommunications region of 1300 nm to 1600 nm. Indeed, over the past several years, stabilized frequency combs have revolutionized frequency metrology and optical clocks. However, prior to the present work, all self-referenced, phase-locked frequency combs used bulk-optic solid-state lasers and covered only the visible and very near infrared. This fiber laser-based comb extends this wavelength coverage 1000 nm further into the infrared. In addition, the fiber laser-based system can be much more compact, robust, power-efficient and lighter than a bulk optic solid state laser system, and can require less alignment. Finally, it can be integrated easily into a telecommunication system.

The phase-locked frequency comb is based on a mode-locked, erbium-doped, fiber laser whose output is amplified and spectrally broadened in novel dispersion-flattened, highly non-linear optical fiber to span from 1100 nm to 2200 nm. This super-continuum actually comprises a comb of frequency lines, separated by the laser repetition rate and with an arbitrary frequency offset. Borrowing the now standard techniques used with Ti:sapphire laser-based systems, researchers phase-locked both the comb spacing and

offset to an RF oscillator. If the RF oscillator is phase-locked to an atomic frequency standard, the comb will form an accurate frequency ruler covering the entire near infrared region from 1100 nm to 2200 nm. Any unknown optical frequency then can be measured by simply comparing its frequency to that of the nearest tooth of the stabilized frequency comb.

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PATENT ISSUED ON NIST INTEGRATING SPHERE-BASED WEATHERING DEVICE

Patent Number 6,626,052, "Method and Apparatus for Artificial Weathering," was assigned to two NIST scientists on Sept. 30, 2003, for the device known as the Simulated Photodegradation via High Energy Radiant Exposure (SPHERE). It can uniformly irradiate test specimens with a high-intensity ultraviolet radiant flux while accurately and precisely controlling this flux, in addition to other weathering elements such as temperature and relative humidity, in order to predict the service life of polymeric materials. The NIST SPHERE provides a source of high-intensity, collimated UV radiation with a spatial uniformity greater than 95 %. Ultraviolet radiant fluxes equivalent to approximately 22 "suns" of solar ultraviolet radiation can be achieved at 32 sphere exit ports. Temperature and relative humidity in the specimen chambers attached to the sphere can also be independently and precisely controlled over wide temperature and relative humidity ranges and over long exposure periods.

Additional information on the NIST SPHERE and the NIST Service Life Prediction Program can be found at http://slp.nist.gov.

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